USACE Asset Management Risk and Reliability Workshop

Condition Index Definitions Primer

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Agenda

- What is a Condition Index (CI)?
- What is their purpose?
- Two examples
  - FHWA Highway Bridges
  - Corps of Engineers Infrastructure
- Why is this important?

What is a Condition Index?

- Numerical score that quantifies the condition of infrastructure
- Characteristics
  - Standardized rating system
  - Data obtained through inspection
  - Designed to be simple
- Expresses a qualitative assessment in quantitative terms

Uses of a Condition Index

- Replacement/repair of individual infrastructure
- Most efficient allocation of maintenance/ repair dollars for a class of infrastructure
- Means of communication state of infrastructure to decision makers
- Forecasting future needs – predicts deterioration rates
- Typically NOT for structural assessment

Highway Bridges

Silver Bridge Collapse

- December 15, 1967
- Rush hour traffic
- 46 fatalities

Congressional inquiries

National Bridge Inspection Standards

Federal Aid Highway Act of 1970

Federal Aid Highway Act of 1970

- All states inspect bridges every two years
- Inspector qualifications
- Inspector training program
- Data collection and reporting requirements
- Special Bridge Replacement Program

National Bridge Inventory

- 592,000 bridges
  - Over 20 feet in length
  - Public roads
- 4 billion vehicles per day
- 300 million square meters of bridge deck

Result: 35 years of data

National Bridge Inventory Condition Ratings

NBI Rating	Description	Repair Action
9	Excellent Condition	None
8	Very Good Condition	None
7	Good Condition	Minor Maintenance
6	Satisfactory Condition	Major Maintenance
5	Fair Condition	Minor Repair
4	Poor Condition	Major Repair
3	Serious Condition	Rehabilitate
2	Critical Condition	Replace
1	Imminent Failure	Close Bridge and Evacuate
0	Failed	Beyond Corrective Action

State Bridge Management Systems

PONTIS BMS

- Investigates specific elements (146 total)
    - Asphalt overlay
    - Steel girders, painted
    - Column or pile extension
    - Pedstrian railings
    - Pin and hangar assembly
    - Elastomeric bearing
    - Filled joint, non-expansion
    - Approach slab
- Specifically considers corrosion, fatigue, cracking, settlement, scour, and alkali-silica reactivity
- Condition tables for each element

PONTIS Rating: Open Steel Girders

CS	Description	Rust Code
1	No evidence of active corrosion	-
2	Slight peeling of the paint, pitting or surface rust	Light R1
3	Peeling of the paint, pitting, surface rust	R1
4	Flaking, minor section loss (<10%)	R2
4	Flaking, swelling, moderate section loss (>10% but <30%). Structural analysis not warranted	R3
5	Flaking, swelling, moderate section loss (>10% but <30%). Structural analysis warranted	R3
5	Heavy section loss (>30% of original thickness), may have holes through the base metal	R4

Linear Condition State Deterioration Models

Table 5: Linear Condition State Deterioration Models for RC Decks, Railings, and RC Substructures (Hearn et al., 1995)

Element	Source	Basis	Time to NBI=4 (years)	Time to NBI = 3 (years)	Deter. Rate (CR/year)
RC Deck	James *et al.* 1993	Data	24	29	0.210
RC Deck	Stukhart *et al.* 1991	Expert	33	39	0.152
RC Deck	Chen and Johnston 1987	Data	41	49	0.123
RC Deck	Morrow and Johnston 1994	Data	45	54	0.111
RC Deck	Al Rahim and Johnston 1991	Data	48	58	0.104
Steel Rail	Morrow and Johnston 1994	Data	37	44	0.135
RC Substructure	James *et al.* 1993	Data	23	27	0.219
RC Substructure	Stukhart *et al.* 1991	Expert	35	42	0.143
RC Substructure	Chen and Johnston 1987	Data	44	53	0.114
RC Substructure	Morrow and Johnston 1994	Data	42	50	0.119
RC Substructure	Al Rahim and Johnston 1991	Data	42	50	0.119

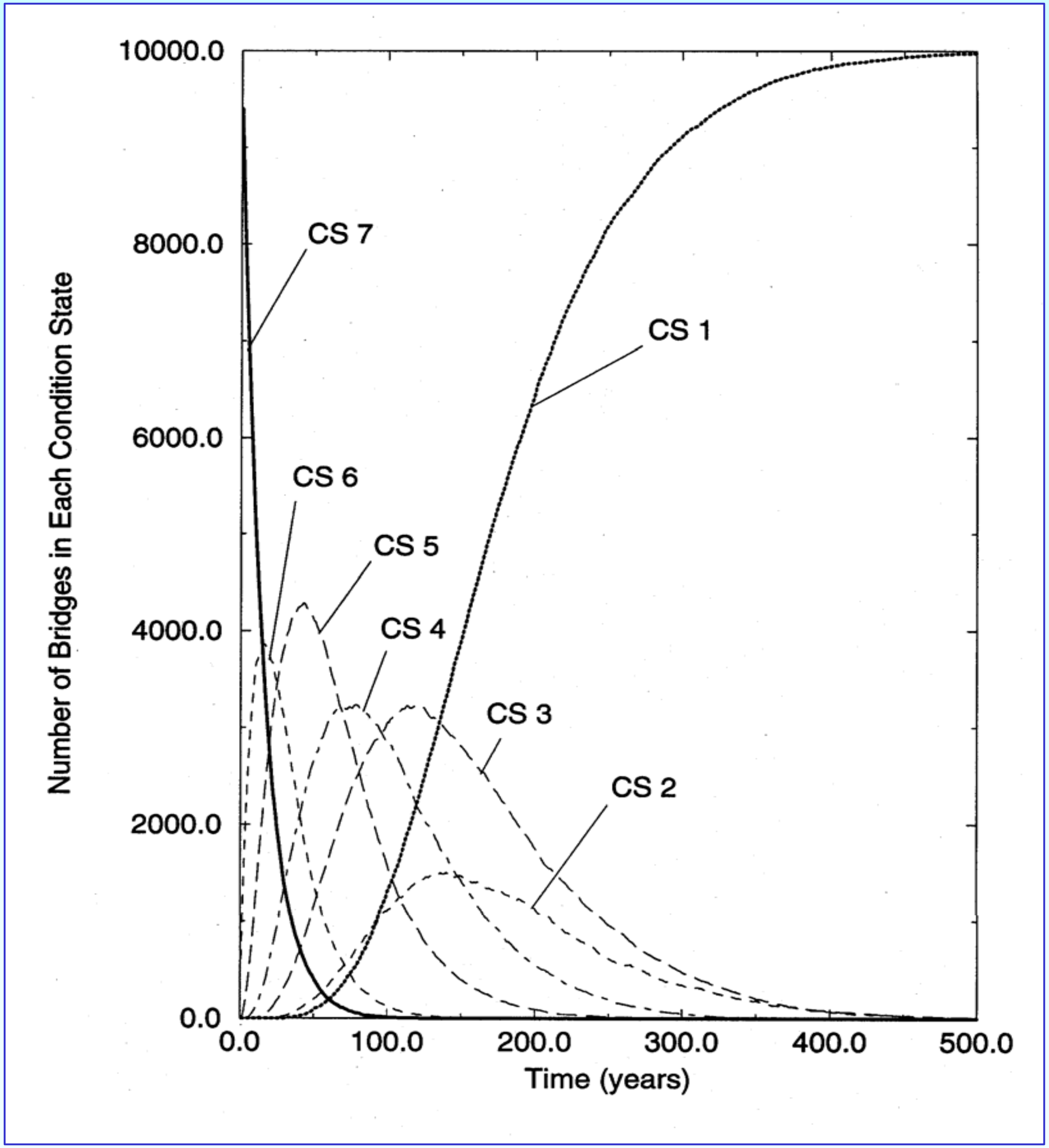
Markov Chains

Table 6: Transition Probabilities for Concrete Bridge Substructures Using Markov Chains (Jiang and Sinha 1989)

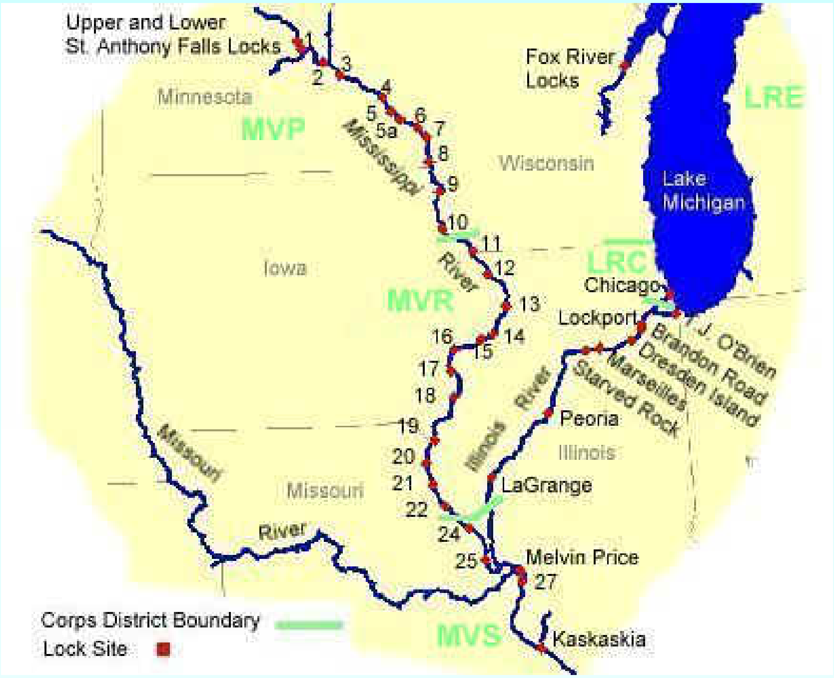
Bridge Age (years)	Transitional Probabilities					
	p_9	p_8	p_7	p_6	p_5	p_4
0-6	0.705	0.818	0.810	0.802	0.801	0.800
7-12	0.980	0.709	0.711	0.980	0.980	0.856
13-18	0.638	0.639	0.748	0.980	0.980	0.980
19-24	0.798	0.791	0.788	0.980	0.870	0.824
25-30	0.794	0.810	0.773	0.980	0.980	0.980
31-36	0.815	0.794	0.787	0.980	0.980	0.737
37-42	0.800	0.798	0.815	0.980	0.850	0.980
43-48	0.800	0.800	0.309	0.938	0.980	0.050
49-54	0.800	0.800	0.800	0.711	0.707	0.768
55-60	0.800	0.800	0.800	0.050	0.050	0.505

p_9 is the probability that the bridge will remain in condition state 9 at the next inspection

Bridge Deck Condition States Using Markov Chains



U.S. Army Corps of Engineers



512 Locks and Dams in National Dam Inventory Database

90% Classified as High Risk Facilities

>80% of all Expenditures for Dams and Reservoirs is for Maintenance

FY04 Corps of Engineers Budget is $4.3 Billion

Over half the locks and dams are over 50 Years old

Inland waterways transport $73 billion annually (630 million tons)

USACE Condition Index

CI Value	Condition Description	Zone	Action
85-100	Excellent; no noticeable defects	1	Immediate Action not required
70-84	Very good: minor deterioration only		
55-69	Good: some deterioration or defects evident	2	Economic analysis of repair alternatives recommended
40-54	Fair: moderate deterioration; function still adequate		
25-39	Poor: serious deterioration; function inadequate	3	Detailed evaluation required to determine need for repair, rehabilitation or reconstruction
10-24	Very Poor: extensive deterioration, barely functional		
0-10	Failed: no longer functional		

Miter Gate: Lock and Dam #12

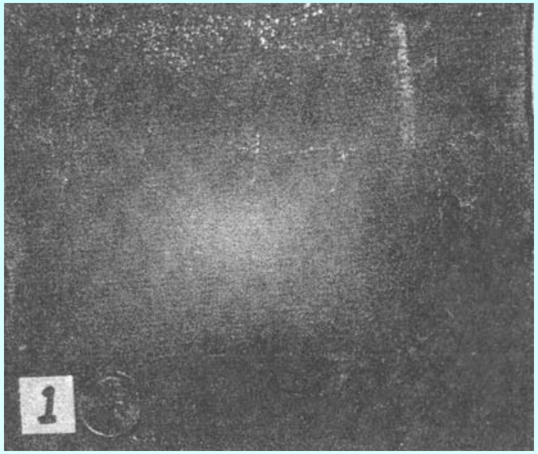
Miter Gate Inspectable Items

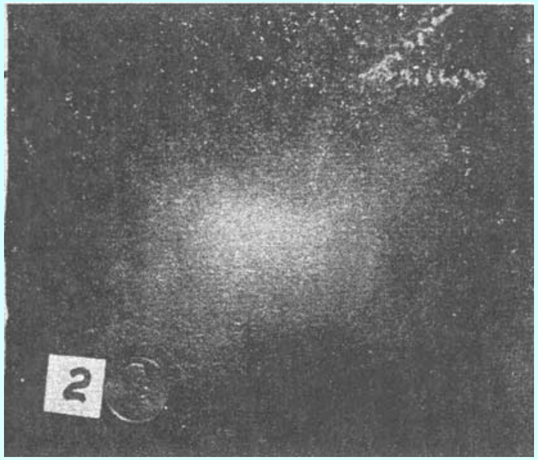
• Corrosion	0.08
• Noise and Vibration	0.11
• Dents	0.02
• Anchorage Movement	0.18
• Elevation Changes	0.14
• Miter Offset	0.08
• Bearing Gaps	0.13
• Downstream Movement	0.11
• Cracks	0.10
• Leaks and Boils	0.05

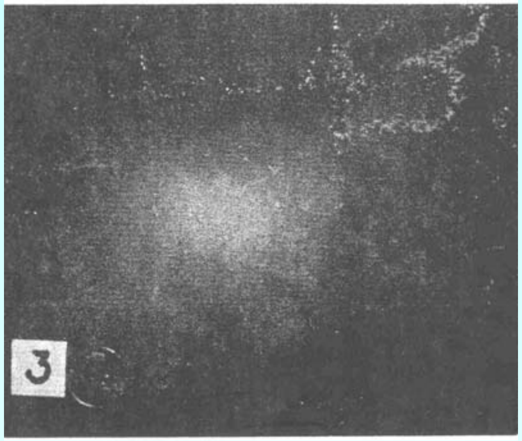
Corrosion Levels

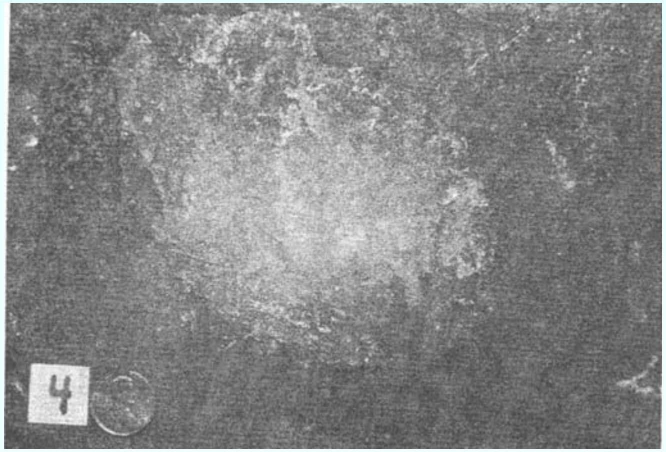
Level	Description
0	New
1	Minor surface scale
2	Moderate pitting
3	Severe pitting
4	Obvious thickness reduction
5	Holes due to thickness reduction

Condition State Guides









CI Inspection Results
Auxillary Miter Gate
Lock and Dam #12

Structural Element	Left Leaf		Right Leaf	
	Up stream	Down Stream	Up stream	Down Stream
Girder	2	2	1	2
Inter coastal	2	2	1	2
Skin Plate	2	2	1	2

Condition State Computation

$$CI_{UG} = CI_{DG} = 100(0.4)^{X/X_{MAX}} = 100(0.4)^{2/3} = 54$$

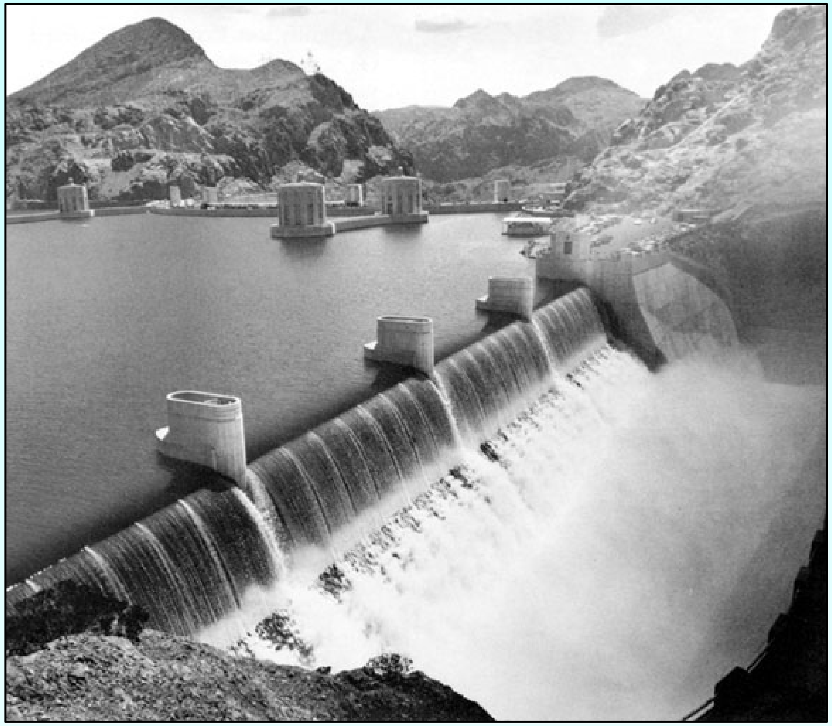
$X_{max\ G}=3$; $X_{max\ S}=4$; $X_{max\ I}=4$

$CI_G=\min(CI_{DG}, CI_{UG})$; $CI_S=\min(CI_{DS}, CI_{US})$;

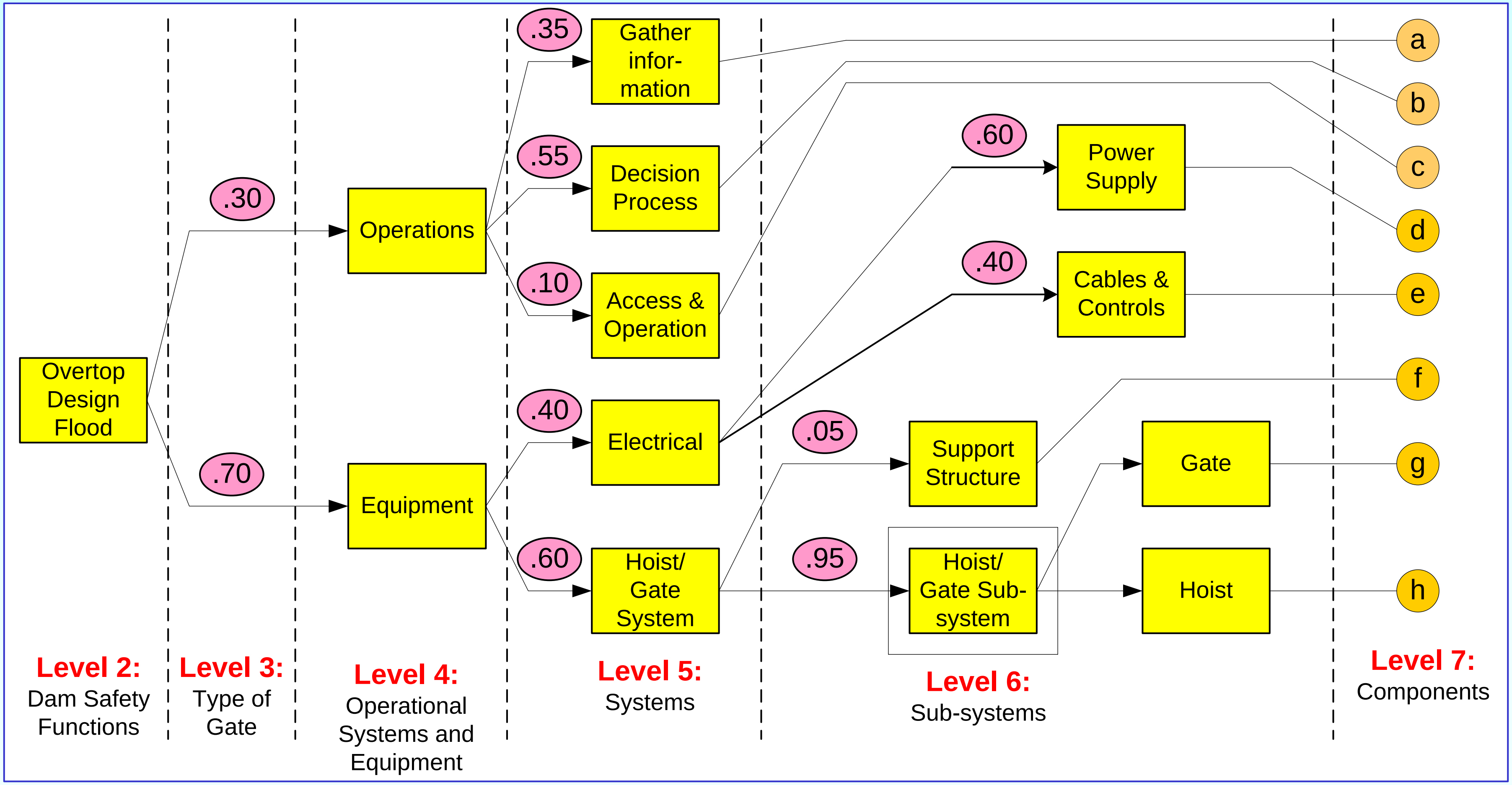
$CI_I=\min(CI_{DI}, CI_{UI})$

$CI = \min(CI_G, CI_S, CI_I)$

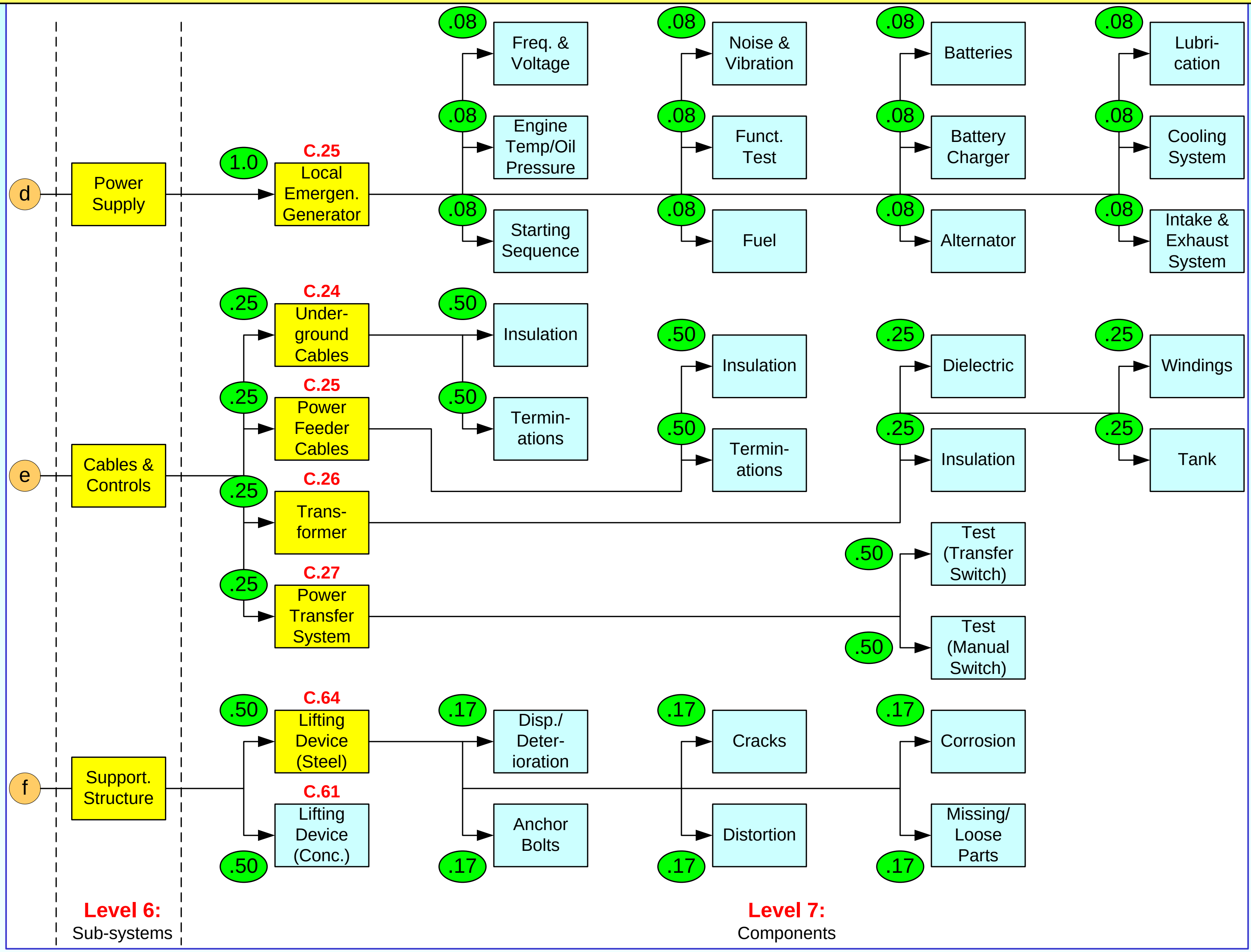
Spillway Gates on Dams



Great Falls Dam



Great Falls Dam



Typical Component Condition Table

	Hoist Brake							
Function	To arrest motion of gate and hold gate in any position							
Excellent	Can arrest motion at any position, not seized							
Failed	Cannot arrest motion at any position, seizing of brake							
Indicator	0-9	10-24	25-39	40-54	55-69	70-84	85-100	Score
Can arrest motion at any position, not seized							x	
Limited slippage without impacting operation; no slip but vibration				x	x	x		
Limited slippage that impacts operation		x	x					
Continuous slippage, seizing of brake	x							

Shortfall in Corps Approach

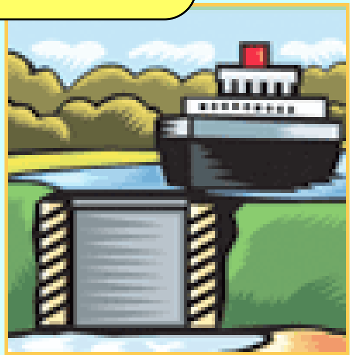
- Inspections not mandated – vary from district to district
- Inspections not resourced
- No centralized collection of data
- No emphasis from highest levels
- Other priorities have taken precedence

Why are Condition Indices Important?

- What happens when disaster strikes?
  - What is the state of the Corps infrastructure?
  - Why haven’t periodic inspections been recorded and systematically collected
  - Why haven’t we learned from the highway department?
- ASCE Report Card

ASCE Report Card





Subject	2001 Grade	2005 Grade	Comments
Bridges	***C***	***C***	Between 2000 and 2003, the percentage of the nation's 590,750 bridges rated structurally deficient or functionally obsolete decreased slightly from 28.5% to 27.1%. However, it will cost $9.4 billion a year for 20 years to eliminate all bridge deficiencies. Long-term underinvestment is compounded by the lack of a Federal transportation program.
Dams	**D**	**D**	Since 1998, the number of unsafe dams has risen by 33% to more than 3,500. While federally owned dams are in good condition, and there have been modest gains in repair, the number of dams identified as unsafe is increasing at a faster rate than those being repaired. $10.1 billion is needed over the next 12 years to address **all critical** non-federal dams--dams which pose a direct risk to human life should they fail.
Navigable Waterways	***D+***	**D-**	A single barge traveling the nation's waterways can move the same amount of cargo as 58 semi-trucks at one-tenth the cost--reducing highway congestion and saving money. Of the 257 locks on the more than 12,000 miles of inland waterways operated by the U.S. Army Corps of Engineers, nearly 50% are functionally obsolete. By 2020, that number will increase to 80%. The cost to replace the present system of locks is more than $125 billion.

Recommendations

- Make condition index inspections mandatory in all districts at specified intervals
- Start with a few structures
- Centrally collect/synthesize the data
- Systematically use the data
  - Communicate current status
  - Make decisions
  - Predict future needs
- Command emphasis and funding

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Questions?

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